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UNITED STATES PATENT APPLICATION

FOR

AUTOMATICALLY ADJUSTING ANNULAR JET MIXER

AUTOMATICALLY ADJUSTING ANNULAR JET MIXER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an automatically self adjusting annular jet mixer useful in mixing guar and other materials to create a fracturing fluid gel at the site of a gas or oil well.

2. Description of the Related Art

Mixing of guar and other material for creating a fracturing fluid gel has been known for approximately 50 years. Fracturing fluids are used to carry or transport proppant, usually sand, into a well fracture for the purpose of creating improved production of hydrocarbons, i.e. oil or natural gas. In the past, guar gel has had quality problems which were evident by lumps of partially hydrated gel within the gel fluid. These lumps could possible plug off formation permeability and also caused reduced viscosity of the gel. The reduced viscosity was caused by not all of the gel being incorporated into the fluid and thus not being fully utilized. Many efforts, some quite elaborate, have been used to produce a quality gel, i.e. one that was free of lumps. Screens have been used to filter out lumps. Grinders and shear devices have been used to break down the lumps. Chemicals have been used to coat the dry gel powder particles to slow the

hydration process and thereby prevent lumps. Guar powder has also been mixed as slurry with diesel fuel to create a concentrated suspension for later mixing into a gel. All these techniques added cost to the material, and depending on the process, added elaborate and expensive equipment. All of these solutions added to the cost of fracturing a well, thus making the produced oil and gas more expensive.

Mixing energy has been found to be an important key to mixing a lump free gel. Guar powder tends to lump if it is not fully wetted when it first encounters water. Thus, a high energy mixer that wets all guar powder particles will create a lump free gel. One of the problems with standard mixers is that the nozzle or jet from which the water exits is usually fixed in size, i.e. the nozzle is not adjustable. If the process rate is changed from the optimal flow for that nozzle, then the performance is changed. If the process rate is less than the optimal rate, then not enough energy will be created to mix the gel free of lumps. In the process rate is much higher than the optimal rate, a high pressure loss is developed in the nozzle which increases required pump horse power and further limits the maximum throughput rate. The most economical fracturing process is one in which the gel is prepared "on-the-fly" at the same time the fracturing fluid is pumped down the well. Guar does need some time to hydrate and develop the desired viscosity. Therefore, a holding tank downstream of the mixer is usually needed before the fluid is mixed with the proppant and is then pumped down the well. Since the characteristics of wells vary greatly, there is a need to mix guar

gels at different rates, depending on the stage and well treatment design. The present invention provides a high energy mixer that also automatically adjusts the nozzle size to maintain a high energy nozzle jet to efficiently mix the gel at a wide range of flow rates. The adjustment means employed in the present invention requires no outside power source or control means, whether electronic, mechanical or hydraulic. The water that is used to mix the gel also creates the power that is used to adjust the mixer nozzle. A pressure reducing valve operating on the process water is used to adjust the mixer pressure setting. Once this setting has been made, no other future adjustments are necessary.

SUMMARY OF THE INVENTION

The present invention is an automatically self adjusting annular jet mixer useful in mixing guar and other materials to create a fracturing fluid gel such as employed at the site of a gas or oil well.

The present invention is provided with an inner nozzle member that is axially movable along the mixer centerline to increase and decrease the size of the effective nozzle opening. Integral with the inner nozzle is a piston. The piston is movable within the housing of the mixer, forming an upstream area on one side of the piston and a downstream area on the opposite side of the piston. The upstream area is larger than the downstream area. The downstream area is connected to the mix water supply pump and the upstream area is connected to the outlet of a pressure regulator. The inlet of the the pressure regulator is the same as the downstream side of the piston, i.e. the mix water pump pressure. Although the pressure in the upstream area is preferably provided by regulated supply water, this is not required and the constant pressure in the upstream area can alternately be provided by another source of water or be pressurized by air or other suitable gas.

The pressure regulator sets the maximum pressure of the upstream side of the piston. This pressure, together with the area ratio of the control piston determines the mix water control pressure. If the mix water pressure is lower than required, then the piston moves the inner nozzle member in a direction that will reduce the nozzle outlet size. Reducing the nozzle size increases the

backpressure. Conversely, if the mix water pressure is too high, then the piston will move the inner nozzle in the opposite direction to increase the nozzle opening and thus reduce the pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a cut away side view of an automatically adjusting annular jet mixer constructed in accordance with a preferred embodiment of the present invention.

FIGURE 2 is a cut away side view of an inner nozzle member of the automatically adjusting annular jet mixer of Figure 1.

FIGURE 3 is an end view of the inner nozzle member taken along line 3-3 of Figure 2.

FIGURE 4 is a cut away side view of a piston of the automatically adjusting annular jet mixer of Figure 1.

FIGURE 5 is a cut away side view of an alignment member of the automatically adjusting annular jet mixer of Figure 1 that prevents the inner nozzle member from rotating as it moves axially along the mixer centerline.

FIGURE 6 is an end view of the alignment member taken along line 6-6 of Figure 5.

FIGURE 7 is a cut away top view of a stationary housing of the automatically adjusting annular jet mixer of Figure 1.

FIGURE 8 is an end view of the housing taken along line 8-8 of Figure 7.

FIGURE 9 is a cross sectional view showing an optional central mix water supply pipe located within centrally within the inner nozzle member.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

THE INVENTION

Referring now to the drawings and initially to Figure 1, there is illustrated an automatically self adjusting annular jet mixer **10** that is constructed in accordance with a preferred embodiment of the present invention. The mixer **10** is a type that is useful in mixing guar and other materials to create a fracturing fluid gel at the site of a gas or oil well.

The mixer **10** is provided with a hollow stationary housing **12** and a hollow inner nozzle member **14** that is axially movable along a centerline **16** of the mixer **10** in order to increase and decrease the size of the effective nozzle opening **18**. A piston **20** is integrally attached to the inner nozzle **14**. The piston **20** encircles an external surface **22** of the inner nozzle **14** so that an enclosed upstream cavity **24** is formed between a first side **26** of the piston **20**, the external surface **22** of the inner nozzle **14**, an inner surface **28** of the housing **12**, and a first end **30** of an alignment member **32**. Also an enclosed downstream cavity **34** is formed on an opposite second side **36** of the piston **20** between the second side **36**, the external surface **22A** of the inner nozzle **14**, and the inner surface **28** of the housing **12**.

The piston **20** and the attached inner nozzle **14** move within the housing **12** of the mixer **10** as a result of the hydraulic pressure exerted on the first side **26** of the piston **20** via the upstream cavity **24** and the hydraulic pressure exerted on the opposite second side **36** of the piston **20** via the downstream cavity **34**.

The upstream area of cavity **24** is defined by the projected area along the mixer axis **16** that has an outer diameter of surface **28** and an inner diameter of surface **22**. The downstream area of cavity **34** is defined by the projected area along the mixer axis **16** that has an outer diameter of surface **28** and an inner diameter of surface **22A**. The upstream area of cavity **24** is larger than the downstream area of cavity **34**. The downstream cavity **24** is connected to and receives supply water from the mix water supply pump **38** via a flow meter **40** as shown in Figure 1 by lines **42, 44, 46, 48A**, and **48B**. As shown by line **42**, mix water is received by the mix water supply pump **38** and is then pumped through the flow meter **40**, as shown by line **44**. From the flow meter **40**, the supply water flows via line **46** and then via lines **48A** and **48B** to two supply water inlets **50A** and **50B**, respectively, that are provided in the housing **12** so that both of the supply water inlets **50A** and **50B** communicate directly with the downstream cavity **34**. The location of the two supply water inlets **50A** and **50B** is best illustrated in Figure 8.

The upstream cavity **24** is connected to and receives supply water from an outlet of a pressure regulator valve **52**, as show by line **54**. Line **54** connects to the upstream cavity **24** via a water inlet **56** provided in the housing **12**. An inlet of the pressure regulator valve **52** receives supply water from the flow meter **40** via line **46**, i.e. the same source that supplies the downstream cavity **34**. The pressure regulator valve **52** sets the maximum pressure of the upstream cavity **24** and determines the force exerted on the first side **26** of the piston **20**. This

pressure, together with the area ratio of the two sides **26** and **36** of the control piston **20** determines the mix water control pressure.

Stated another way, the product of the regulated pressure that is exerted on the first side **26** of the piston **20** and the area of the first side **26** of the piston **20** on which that regulated pressure is exerted will remain equal to the product of the pressure exerted by the water flowing from the mix water supply pump **38** and the area of the second side **36** of the piston **20** on which that pressure is exerted. These two products will always remain equal in the mixer **10** due to the free axial movement of the piston **20** which keeps the forces exerted on the first and second sides **26** and **36** of the piston **20** in balance. Since the pressure regulator valve **52** maintains a constant pressure on the first side **26** of the piston **20** and the area of the first side **26** of the piston **20** is constant and the area of the second side **36** of the piston **20** is constant, the piston **20** moves in proportion to the pressure exerted on the second side **36** of the piston **20** by the mix water supply pump **38**. Thus, the mixer **10** automatically adjusts to the flow and the resulting pressure exerted by the flow emanating from the mix water supply pump **38**. If the mix water pressure is lower than required, then the piston **20** moves the inner nozzle member **14** in a direction, as illustrated by **Arrow A** in Figure 1 that will reduce the size of the nozzle opening or outlet **18**. Reducing the size of the nozzle opening **18** increases the backpressure, thus balancing the opposing forces being exerted on the piston **20** via the upstream and downstream areas. Conversely, if the mix water pressure is too high, then the

piston **20** will move the inner nozzle **14** in the opposite direction, as illustrated by **Arrow B**, to increase the size of the nozzle opening **18** and thus reduce the backpressure, thus again balancing the opposing forces being exerted on the piston **20** via the upstream and downstream areas.

Self adjustment of the nozzle opening **18** in coordination with the supply water flow is important since this maximizes wetting of the guar gum powder which enters a powder inlet opening **58** provided in the mixer **10** via the route indicated by **Arrow C**. This route of entry of the guar gum powder is typical of this type of mixer and the guar gum powder is usually blown via air stream into the mixer **10**. It is also possible to have gravity feed of the guar powder to the mixer **10**. In addition, the mixer **10** creates a vacuum on the powder inlet opening **58** and thus induces an air flow which is capable of transporting powder to the mixer **10** without other motive means. Any of the three means is a satisfactory method of delivering guar powder to the mixer **10**.

Also, as illustrated in Figure 9, an optional central mix water supply pipe **59** supplying additional mix water is an option for mixtures requiring higher flow rates or more difficult to mix materials. The central pipe jet **61** provided in the central mix water supply pipe **59** where it terminates within the mixer **10** will add flow capacity and mixing energy. An opposite end of the central mix water supply pipe **59** is connected to a supply of mix water. The mix water and the guar gum powder are thoroughly mixed together in the mixer **10** immediately downstream of the nozzle opening **18** and the guar gum mixture exits the mixer

10, as illustrated by **Arrow D** in Figure 1, via a mixture exit opening **60** provided in the housing **12** of the mixer **10**. Subsequent to exiting the mixer **10**, entrained air is removed from the mixture via traditional means and the guar gel mixture is then ready to be pumped into an oil or gas well as part of a fracturing job. As previously noted, guar does need some time to hydrate and develop the desired viscosity, and therefore, a holding tank downstream of the mixer **10** is usually needed before the fluid is mixed with the proppant and pumped down the well.

Referring now to Figures 1, 2 and 3, structural details of the inner nozzle **14** are illustrated. As illustrated in Figure 2, a tapered section **62** of the external surface **22** of the nozzle **14** is tapered inwardly at the discharge end **64** so that the nozzle **14** decreases in its exterior diameter toward the discharge end **64**. As shown in Figure 1, the tapered section **62** of the nozzle **14** moves axially within an inwardly tapered portion **66** of the housing **12** so that the nozzle opening **18** is formed between the tapered section **62** of the nozzle **14** and the tapered portion **66** of the housing **12**. Obviously, as the nozzle **14** moves axially within the housing **12**, the nozzle opening **18** will decrease when the movement is in the direction of **Arrow A**, or alternately, will increase when the movement is in the direction of **Arrow B**.

The inner nozzle **14** is provided externally with the shoulder **72** for retaining the piston **20** on the second side **36** of the piston **20** and is provided externally with an indented area **74** where a piston retaining ring **75** seats to retain the piston **20** on the first side **26** of the piston **20**.

Also, an opposite inlet end **76** of the nozzle **14** is provided with a traveling pin groove **78** in its external surface **22** for movably retaining a traveling pin **80** that inserts through a traveling pin opening **82** provided in an arm **84** of the alignment member **32**. The inlet end **76** of the nozzle **14** is also provided with means for securing the nozzle **14** to existing equipment for introducing guar gum powder into the mixer **10**, such as groove **86** for receiving a connecting collar **88**.

Referring now to Figure 4, the detailed structure of the piston **20** is illustrated. Figure 4 shows a cut away side view of the circular piston **20** that secures to the inner nozzle member **14**. The piston **20** is provided with a single helical groove **90** in the piston's external surface **92**. The purpose of the helical groove **90** is to allow water to flow via the groove **90** between the upstream and downstream cavities **24** and **34**. This flow of water within the groove **90** and between the external surface **92** of the piston **20** and the inner surface **28** of the housing **12**, thereby serves as a lubricant between the piston **20** and the inner surface **28** of the housing **12**. The water flow within the groove **90** balances the pressures around the piston **20**, thereby allowing the movable assembly, i.e. the piston **20** and the inner nozzle **14**, to move more easily. Also, the groove **90** allows small particulates to pass without damaging surfaces. The lubrication provided by the water facilitates axial movement of the piston **20** and the attached inner nozzle **14** as a single unit within the housing **12**.

Referring now to Figures 1, 5, and 6, the detailed structure of the alignment member **32** is illustrated. As previously described, the first end **30** of

the alignment member **32** is provided with the arm **84** that extends longitudinally parallel with and adjacent to the external surface **22** of the inner nozzle **14**. The arm **84** holds the traveling pin **80** within its traveling pin opening **82** and the traveling pin **80** extends downward into the groove **86** in the nozzle **14**, thereby preventing the nozzle **14** from rotating relative to the housing **12** as the nozzle **14** moves axially within the housing **12**.

The alignment member **32** is provided with a helical groove **94** in the inner surface **96** of the hollow alignment member **32**. The helical groove **94** encircles the inner surface **96** a plurality of times. The helical groove **94** is located at the opposite second end **98** of the alignment member **32**. The helical groove **94** is similar to the helical groove **90** provided in the piston **20** in that it allows water to flow through it so that the water can act as a lubricant. A small amount of water flows from the upstream area **24**, between the inner surface **96** of the alignment member **32** and the external surface **22** of the inner nozzle member **14** via the helical groove **94**, and out of the mixer **10** via a drain opening **100** provided in and extending completely through both the alignment member **32** and the housing **12**. Although the amount of water traveling through the helical groove **94** is small, it is an amount sufficient to lubricate the surfaces **96** and **22** and facilitate the axial movement of the inner nozzle member **14** and the attached piston **20** within the housing **12** without appreciably affecting the fluid pressure in the upstream area **24**.

The alignment member **32** is also provided with a low pressure seal **102** that resides in a seal indentation **104** that encircles the inner surface **96** of the hollow alignment member **32** adjacent to the arm **84**. The low pressure seal **102** serves to prevent leakage of water from between the alignment member **32** and the inner nozzle member **14** upstream of the drain opening **100**. The alignment member **32** secures to the housing **12** via set screws **106** that extend through set screw openings **107** provided in the housing **12** and engage set screw grooves **108** provided for this purpose in an external surface **110** of the alignment member **32** adjacent the first end **30** of the alignment member **32**. The external surface **110** of the alignment member **32** is also provided with indentations **109** for seals **111**. The alignment member **32** is also contained within the housing **12** by an internal snap ring **113**, as illustrated in Figure 1.

Referring now to Figures 7 and 8, there is illustrated detailed structure for the housing **12**. Figure 7 shows the housing **12** as being composed of approximately six distinct portions **112, 114, 116, 118, 120**, and **122**. Starting at the inlet end **76** and proceeding toward the mixture exit opening **60** of the housing **12**, the portions encountered are as follows: a first portion **112** to which the alignment member **32** secures; a second portion **114** which is slightly smaller in diameter than the first portion 112 and houses the upstream cavity **24** and the movable piston **20**; a third portion **116** which is slightly larger in diameter than the second portion 114, houses the downstream cavity **34**, and is provided with supply water inlets **50A** and **50B** that communicate through the housing **12;** a

fourth portion **118** which includes a sloped area **119** that decreases in diameter from the third portion **116** and allows water to flow from the downstream cavity **34** into the tapered section **62** of the inner nozzle member **14**; a fifth portion **120** which further decreases in diameter from the fourth portion **118** and includes the previously described inwardly tapered portion **66** of the housing **12**; and a sixth portion **122** which increases in diameter form the fifth portion **120** and includes an outwardly expanding tapered portion **124** that terminates at the mixture exit opening **60** of the housing **12**.

As illustrated in Figure 8, each of the supply water inlets **50A** and **50B** is provided with a groove, **126A** and **126B** respectively, for securing water lines **48A** and **48B** to the housing **12** at the supply water inlets **50A** and **50B**. Also, the mixture exit opening **60** of the housing **12** is provided with a groove **128** for securing the mixer **10** to typical downstream equipment, such as degassing equipment (not illustrated), prior to the guar gel mixture being pumped into a holding tank and fracturing blender and subsequently into an oil or gas well during a fracturing job.

While the invention has been described with a certain degree of particularity, it is manifest that many changes may be made in the details of construction and the arrangement of components without departing from the spirit and scope of this disclosure. It is understood that the invention is not limited to the embodiments set forth herein for the purposes of exemplification,

but is to be limited only by the scope of the attached claim or claims, including the full range of equivalency to which each element thereof is entitled.